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BRIEFER ARTICLES.

NEW PRECISION-APPLIANCES FOR USE IN PLANT PHYSIOLOGY. II.¹

(WITH FOUR FIGURES)

IN the first of these articles I gave the reasons which have led to the development of some new pieces of apparatus for educational use in plant physiology, and I described two of these pieces. In brief, believing that improvised apparatus has been brought to its fullest practicable, if not to an actually harmful, degree of development, I am trying to devise for each of the leading physiological topics appropriate normal apparatus, viz., appliances which, manufactured expressly for the specific work, will yield accurate quantitative results, will be applicable to their work with economy of time and effort, and will be obtainable by purchase at any time from the stock of a supply company. In the foregoing article I described the new clinostat and the new portable clamp-stand; below are accounts of three additional appliances, and similar descriptions of other pieces in advanced preparation will follow later. They all are now, or soon will be, for sale by the Bausch & Lomb Optical Company, of Rochester, N. Y.

III. AUTOGRAPHIC TRANSPIROMETER.

A practicable and obtainable form of autographic (self-registering) transpirometer, suitable for use both in educational demonstration and also in certain lines of investigation, is one of the first desiderata of plant physiology. Several forms have been devised, of which the best known are the "évaporomètre" of Richard Frères, and the registering balances of Woods and of Anderson. The first of these, while obtainable, has serious limitations both in practice and in principle; while the two others, though admirable in their accuracy, must be made to order at large cost and with much delay, and they are somewhat elaborate withal. My new instrument, illustrated in the accompanying *fig. 1*, is constructed as follows: A cylinder, shown in the upper part of the figure, contains on a spiral track between its outer and an inner wall some 250 spherical gram weights. These weights are steel bicycle balls of one-fourth inch diameter, the same as Anderson used in his balance; they weigh almost exactly one gram each.

¹ Continued from 37:307. April 1904.

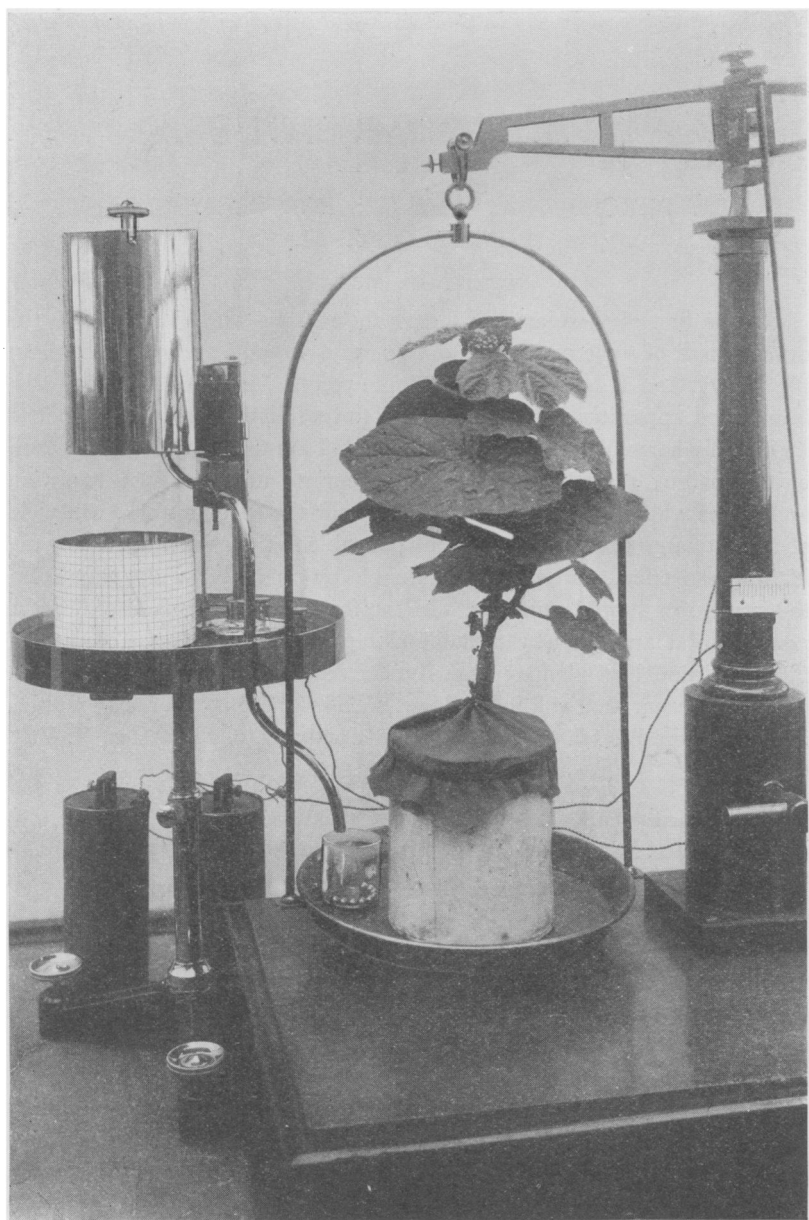


FIG. 1.

and vary not over one-thousandth of this weight from one another. These feed by gravity, one at a time, into a simple releasing valve, so arranged that when acted on by an electro-magnet a slide rises and allows one ball to drop through a tube into a scale pan, a new ball immediately taking its place in the releaser-slide. Attached to the releaser-slide is a bar carrying a pen, so adjusted that every time the slide moves, that is, every time a ball is dropped, the pen makes a vertical fine line with chronographic ink upon a record paper attached to a revolving drum. In use the plant to be studied is prepared in the manner usual for transpiration studies, and is balanced on a scale pan of any good balance, while the transpirometer is adjusted beside it. As the plant loses water this pan rises, and at the

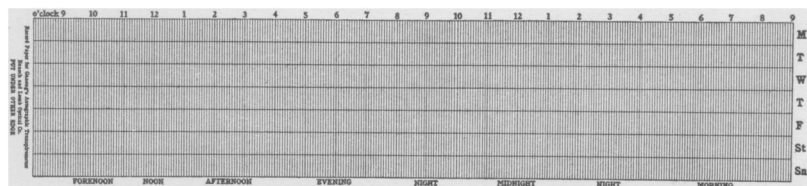


FIG. 2.—One-third the true size.

top of its swing is made to touch a wire, thus closing an electric circuit; this excites the electro-magnet, which then raises the releaser-slide, dropping a ball into the scale pan (which is immediately depressed, breaking the circuit), and making a mark on the record paper. This operation is repeated thereafter every time the plant has lost a gram of water. The drum revolves once in twenty-four hours, and the record paper, a reduced copy of which is presented in the accompanying *fig. 2*, is divided into numbered spaces corresponding to the hours; these spaces are subdivided into twelve parts, each therefore representing five minutes,² and these in turn can easily be read by estimation to fifths, or one-minute intervals. It is possible, therefore, to read off from the drum directly the number of minutes it takes the plant to lose one gram of water, data which are readily transformable into other terms. The record paper is divided into seven horizontal spaces, marked by initial letters, one for each day of the week. The pen slides on the bar, which contains seven notches; and each day, when the plant is watered and the clockwork is wound, the pen is slipped along the bar one notch. Each record paper therefore contains a complete

² These five-minute spaces are exactly 1mm broad; hence millimeter cross-section paper may be used instead of the record paper. This happened to be the case at the time the photograph (*fig. 1*) was made.

record for a week. The tripod stand is adjustable for height, and can be leveled, while the mechanism in use is protected by a glass bell-jar.

Such is the instrument in its present form.³ For some special purposes, such as for use out of doors, it would be better to have the weight-cylinder and the recording drum separated, so that the latter may be removed to any desired place in laboratory, lecture-room, or elsewhere. Probably this form will later be obtainable. For greenhouse and general demonstration use, however, the arrangement figured will be found most convenient. The releaser and reservoir are arranged for gram weights, which are the only ones likely to be needed in educational work. For special investigation purposes lighter or heavier balls could of course be used after appropriate alterations in the size of reservoir and releaser. The instrument may be used with any balance sensitive to a gram; but a special balance, adapted expressly for transpiration work, and provided with a mechanism to prevent oscillation under action of the wind, is in preparation, and will later be described.

IV. ADJUSTABLE LEAF-CLASP.

In several phases of the study of the physiology of leaves it is necessary to apply some object or special device to two exactly corresponding areas of the two surfaces of a leaf. The most familiar instance of this occurs in the application of Stahl's cobalt chloride method to the study of transpiration, and there are other cases nearly as important. For these purposes some simple devices are improvised from clamps, watch-crystals, mica, etc., but there is at present no obtainable appliance by which this end can be accomplished with certainty, celerity, and convenience. The new leaf-clasp, designed to meet this need, is illustrated in the accompanying *fig. 3*, and is constructed as follows. Two similar brass rings, "chamber-rings," each 30^{mm} in diameter and 5^{mm} in depth, are attached at the ends of parallel flexible-elastic bars, so arranged that they hold the rings firmly and exactly edge to edge, while allowing of their separation, by means of a screw, to any desired extent.⁴ For each ring there are provided two accessory rings. One of these is right-angled in section and holds a removable cover-glass, so that when pushed over the exposed edge of the chamber-ring, it converts the latter into a glass-topped chamber, as shown in the figure. If disks of filter paper treated with cobalt chloride (and

³ While this description is in press it has been decided, in order to give the instrument greater compactness, to place the weight-cylinder and recording drum side by side, instead of one above the other.

⁴ In the final form of the instrument, a second screw, not shown in the figure, has been added, permitting the rings to be brought still more tightly together if needful.

preferably cut slightly larger than the chamber-rings so they will cling half-way up the latter) be placed in the chambers, which are then applied to the leaf, the change of color in transpiration may be observed with the greatest clearness and facility. Incidentally, the tightness of the chambers (when not on the leaf) permits the papers to retain their dryness and red color for a considerable time, so that there is no need of haste in applying them to the plant. The second accessory ring is broken, and is intended to hold tinfoil or any fabric tightly to the chamber-ring. Thus if projecting

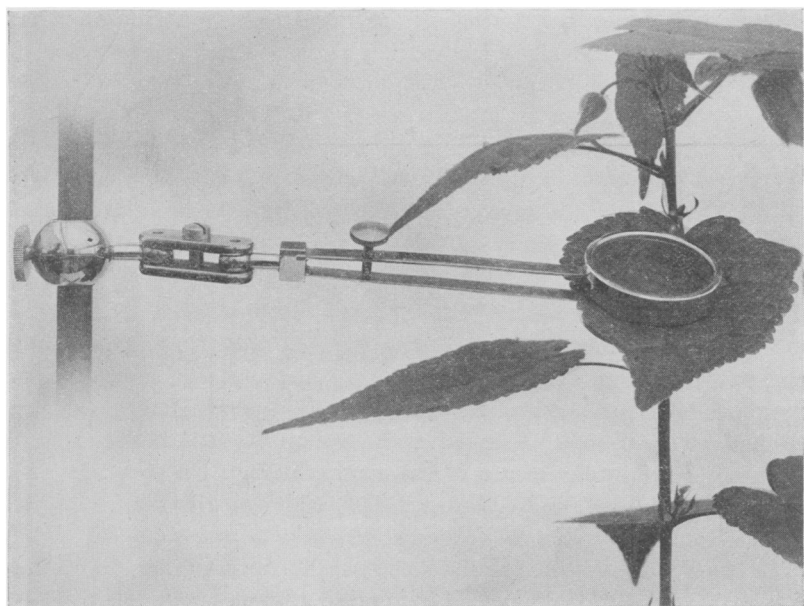


FIG. 3.

veins prevent a connection of chamber with leaf sufficiently tight for some special purposes, a band of thin rubber may be held by the broken ring in such a way that it will project against the leaf, filling the spaces between the veins. But there is a more important use for the broken ring, which is to attach tinfoil patterns or screens to the chamber-rings for the demonstration of the necessity of light in photosynthesis. The common method of demonstrating this important physiological fact by use of corks or other material attached to both faces of a leaf is fallacious (since the absence of starch thus shown is due as much to absence of carbon dioxid as to absence of light), and a logical proof involves use of

a method which cuts off light without cutting off the carbon dioxide. Most leaves have all, or most, of their stomata on the under surface, so that if this is left free, the upper surface may be covered by screens as closely as desired. By means of the broken ring a tinfoil screen, with a pattern cut therein, (preferably backed by a thin glass), or a photographic film or similar device may be attached to the inner edge of one chamber; this is then applied to the upper face of a leaf, with the lower chamber-ring pressing the leaf firmly against it. The access of light is now shut off from the lower surface by a simple accessory diaphragm arrangement (not shown in the figure), which does not impede gas passage; and such an arrangement gives a perfectly logical, and beautifully clear and conclusive demonstration of the necessity of light for starch formation. Of course, this end may be attained by simpler make-shift devices; the virtue of this instrument consists simply in the facility and certainty with which the end may be reached. As shown by the figure, a universal joint and a screw-joint fitting over any upright support permit the apparatus to be adjusted at any desired height, plane, or angle.

V. LEAF-AREA CUTTER.

The most striking and conclusive way of demonstrating the fundamentally important fact of increase of organic substance through photosynthesis is by SACHS'S method of comparing the morning and evening dry weights of equal areas of similar green tissue; but it is rarely employed because of the inconvenience of the manipulation. The leaf-area cutter here figured (*fig. 4*), and described below, is designed to permit all parts of this valuable experiment to be performed with exactness and facility. The cutter works on the principle of a punch; the steel dies, operated by proper handles, cut disks cleanly from a leaf between them, the disks then dropping into a perforated aluminum cup screwed below the lower die. The diameter of the punch-dies is as nearly as possible 1.128cm^2 , and hence every disk is nearly 1cm^2 in area. In use the arms of the punch are slipped above and below the leaf, when the disks may be cut very conveniently and rapidly, in any desired number, care being taken to avoid the larger veins. The larger the number taken the better, since local variations in thickness, etc., may thus be compensated, and 100 is a fair number. The cup is then unscrewed and covered by its own screw cap, which projects sufficiently to allow the cup to hang near the top of an ordinary test tube, as shown in the figure. Water in the bottom of the test tube is then boiled in the gas flame (a convenient holder for the test tube being shown in the figure), and the steam enters the perforations of

the cup, killing the living cells of the disks, thus preventing any loss of weight by respiration. The cup with its contents is then placed in the drying oven. In the evening, using the other cup, an equal number of disks is cut from corresponding positions in similar leaves, or, better, is cut from the second halves of leaves, from the first halves of which the morn-

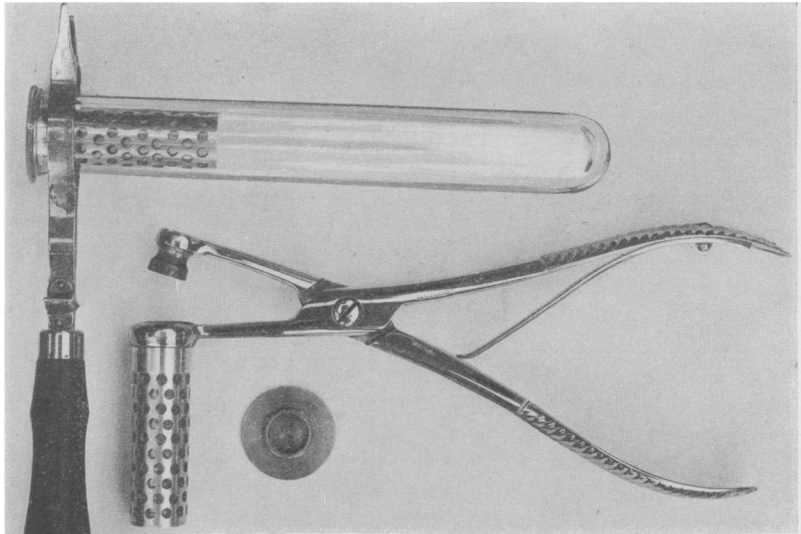


FIG. 4.

ing disks were taken. These are treated as for the first series and the cup is placed beside the first in the drying oven. When thoroughly dry both cups are carefully weighed, the weights of the cups (stamped upon them, together with the letters *M* and *N* respectively to distinguish

the morning and night cups) are subtracted, when the remainder gives the dry weight, which is always greater for the evening than for the morning set. If steps be taken (by use of the methods described by SACHS) to eliminate transfer of material into the stem, the difference in the weights shows approximately the amount of substance formed through photosynthesis in the particular plant studied in so many hours per so many square centimeters of surface. In practice the performance of the instrument is very satisfactory.

In addition to the above-mentioned educational demonstration use, the instrument should also serve in those phases of ecological investigation where it is desirable to determine the relative photosynthetic powers of

various sun and shade plants, or of the same plants under sun and shade conditions. It should also permit of the determination of the photosynthetic constants of many ecologically important plants, as a part of their physiological life-histories, without a knowledge of which their real relations to their physical environment and to other competing plants cannot be understood.—W. F. GANONG, *Northampton, Mass.*